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APPENDIX: TECHNICAL APPROACH TO PATHWAYS ANALYSIS - GARDEN SOIL TO MAN

TOPICAL REPORT (VOL. 2)

for

U.S. DEPARTMENT OF ENERGY
Oak Ridge Operations Office

June 1983

#1115

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June 1983

DOE Contract Number DE-AC05-83OR21355

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

NOTICE

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APPENDIX: TECHNICAL APPROACH TO PATHWAYS ANALYSIS AND STANDARDS COMPARISON

TOPICAL REPORT (VOL. 2)

for

ENVIRONMENTAL PROTECTION BRANCH
SAFETY AND ENVIRONMENTAL CONTROL DIVISION

U.S. Department of Energy
Oak Ridge Operations Office

June 1983

DOE Contract Number DE-AC05-83OR21355

BATTELLE
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505 King Avenue
Columbus, Ohio 43201

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for

U.S. DEPARTMENT OF ENERGY
Oak Ridge Operations Office

from

BATTELLE
Columbus Laboratories

June 1983

1.0 TASK ABSTRACT

The Environmental Protection Branch of the Oak Ridge Operations Office, U.S. Department of Energy (U.S. DOE), is in the process of renewing National Pollutant Discharge Elimination System (NPDES) permits for plant site effluents. During the course of this application, the question of the significance of releases prior to the initiation of permitting of the Oak Ridge facilities has resulted in the evaluation of isotope and chemical concentrations in the environment.

The focus of this analysis is on selected historical releases from the Y-12 Plant and the potential deposition of chemicals in the sediments of the East Fork Poplar Creek. As an example of historical releases, it was estimated in a June, 1977, report that as much as 2.4 million pounds of mercury cannot be accounted for or was lost in releases to the ground, water, and air (U.S. DOE, 1983). The mercury was used in a large-scale lithium separation process at the Y-12 Plant between 1950 and 1963 (U.S. DOE, 1983). The process has not been used since 1963. The releases to the East Fork Poplar Creek during the period were accompanied by radionuclides and PCBs also associated with the plant processes.

1.1 Purpose of the Analysis

The purpose of the analysis was to evaluate pathways to man for five contaminants (uranium, thorium, plutonium, mercury, and PCBs) using available literature, state-of-the-art predictive models, and regulatory exposure levels. The analysis was designed to determine potential exposure levels and risks for the hypothetical scenarios of human exposure via garden contamination and subsequent garden vegetable consumption. The pathways considered in the analysis included the food pathway (for all five substances), the inhalation pathway (for radionuclides only), and the direct exposure pathway (for radionuclides only). Since there was limited availability of excavated stream sediments for garden application and no specific documented garden scenario data were available, the analysis was conducted from scenarios developed from conservative data and reasonably conservative uptake pathways. This approach permitted the evaluation of reasonably worst-case conditions.

This analysis, a component of DOE's review of past practices, was conducted using information, including source data, background information, and conditions provided at a project scoping meeting conducted by the U.S. Department of Energy on May 6, 1983, in Oak Ridge, Tennessee. Detailed assumptions and scenarios based on this input were developed in the course of this analysis.

1.2 Postulated Scenario

The basis for this analysis is the postulated scenario wherein sediment from a creek is assumed to be placed as a soil amendment on a hypothetical garden to improve the tilth of the garden soil. The sediment is assumed for the scenario to contain five contaminants (uranium, thorium, plutonium, mercury, and PCBs). See Attachment A for sediment sampling data used in the analysis. The concentrations of the contaminants are assumed at two observed levels, a high and second high concentration, or in the case of mercury an intermediate concentration. In addition, sediment application is assumed at three levels resulting in three sediment to soil dilutions (0.5, 0.167, and 0.034). Lastly, the level of home garden utilization is assumed at two levels. These levels include: 100 percent of annual vegetable intake is from the garden, consumed on a year round basis (365 days) and 33 percent of annual vegetable intake is from the garden, consumed during the growing season only (120 days).

Based on these general assumptions, a series of twelve specific scenarios were developed for application in the analysis. See Attachment B for a complete listing of assumptions used in the analysis. A schematic of the twelve scenarios is shown in Figure 1.1.

FIGURE 1.1 SCHEMATIC OF SCENARIOS DEVELOPED FOR PATHWAY ANALYSIS

Level of Contaminant in Sediment	Sediment to Soil Mix	Level of Home Garden Utilization
Highest Observed Value	0.5	100 percent
		33 percent
	0.167	100 percent
		33 percent
	0.034	100 percent
		33 percent
Second Highest Observed Value[a]	0.5	100 percent
		33 percent
	0.167	100 percent
		33 percent
	0.034	100 percent
		33 percent

[a] Intermediate data point used for mercury.

2.0 TECHNICAL APPROACH

2.1 Radionuclide Analysis

This section describes the methods and data used to calculate the radiation doses presented in the main body of the report. The calculations involve consideration of the sources and the exposure pathways.

2.1.1 Radionuclide Sources

The primary radionuclide source is contaminated sediment mixed with garden soil. Sediment concentrations of U-235, U-238, Th-232, P_u-238, and P_u-239 were provided along with information that the concentrations of the daughter products U-234 and Th-228 were in equilibrium with their respective parents (U-238 and Th-232). The known decay schemes of these radionuclides are given in Figures 2.1. through 2.5 (ICRP 1979b). Many of the daughter products shown in these figures have short half-lives and, except for including their radiological properties in dose calculations, these daughter products can be ignored. However, those with relatively long half-lives (e.g., greater than one year) will form their own sources which may be redistributed along the exposure pathways in a manner different than the parent. The concentrations of daughter products in activity units (pCi), can be calculated by the expression:

$$q_n = q_o \prod_{j=1}^{n} \lambda_j \left[\prod_{j=1}^{n} (\lambda_j - \lambda_o)^{-1} + \sum_{i=1}^{n} \exp(-(\lambda_i - \lambda_o)t) \prod_{\substack{j=o \\ j \neq i}}^{n} (\lambda_j - \lambda_i)^{-1} \right] \qquad (1)$$

where q_n is the activity of the nth daughter product,

λ_j is the radioactive decay rate of the jth daughter product ($\lambda_j = \ln(2)/T_j$ where T_j is the half life),

q_o is the activity of the parent, and

t is time during which the decay process has occurred.

Th-232 (1.405 E10)
↓
Ra-228 (5.750 E0)
↓
Ac-228 (6.998 E-4)
↓
Th-228 (1.913 E0)
↓
Ra-224 (1.003 E-2)
↓
Rn-220 (1.763 E-6)
↓
Po-216 (4.756 E-9)
↓
Pb-212 (1.215 E-3)
↓
Bi-212 (1.152 E-4) $\xrightarrow{35.93\%}$ Tl-206 (5.841 E-6)
↓ 64.07%
Po-212 (9.671-15) ← Tl-206
↓
Pb-208 (stable)

FIGURE 2.1. DECAY SCHEME FOR Th-232. Numbers in parenthesis are half-lives in years. Data from ICRP (1979b).

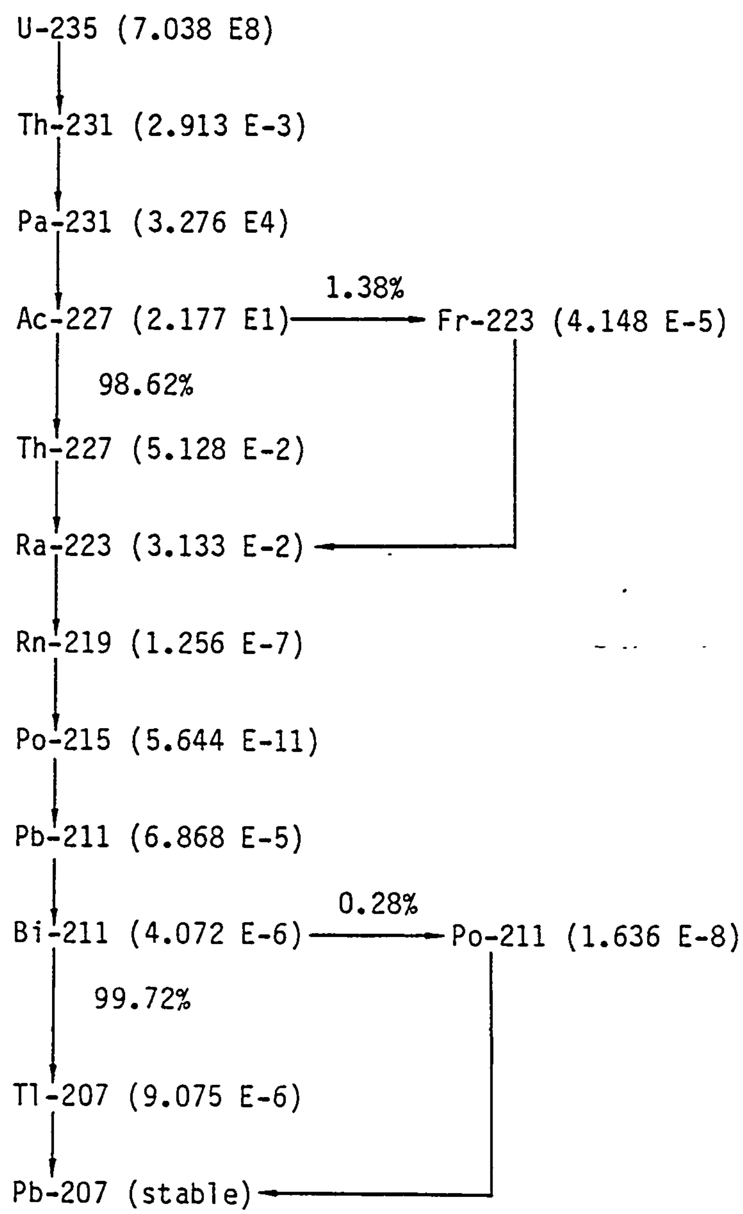


FIGURE 2.2. DECAY SCHEME FOR U-235. Numbers in parenthesis are half-lives in years. Data from ICRP (1979b).

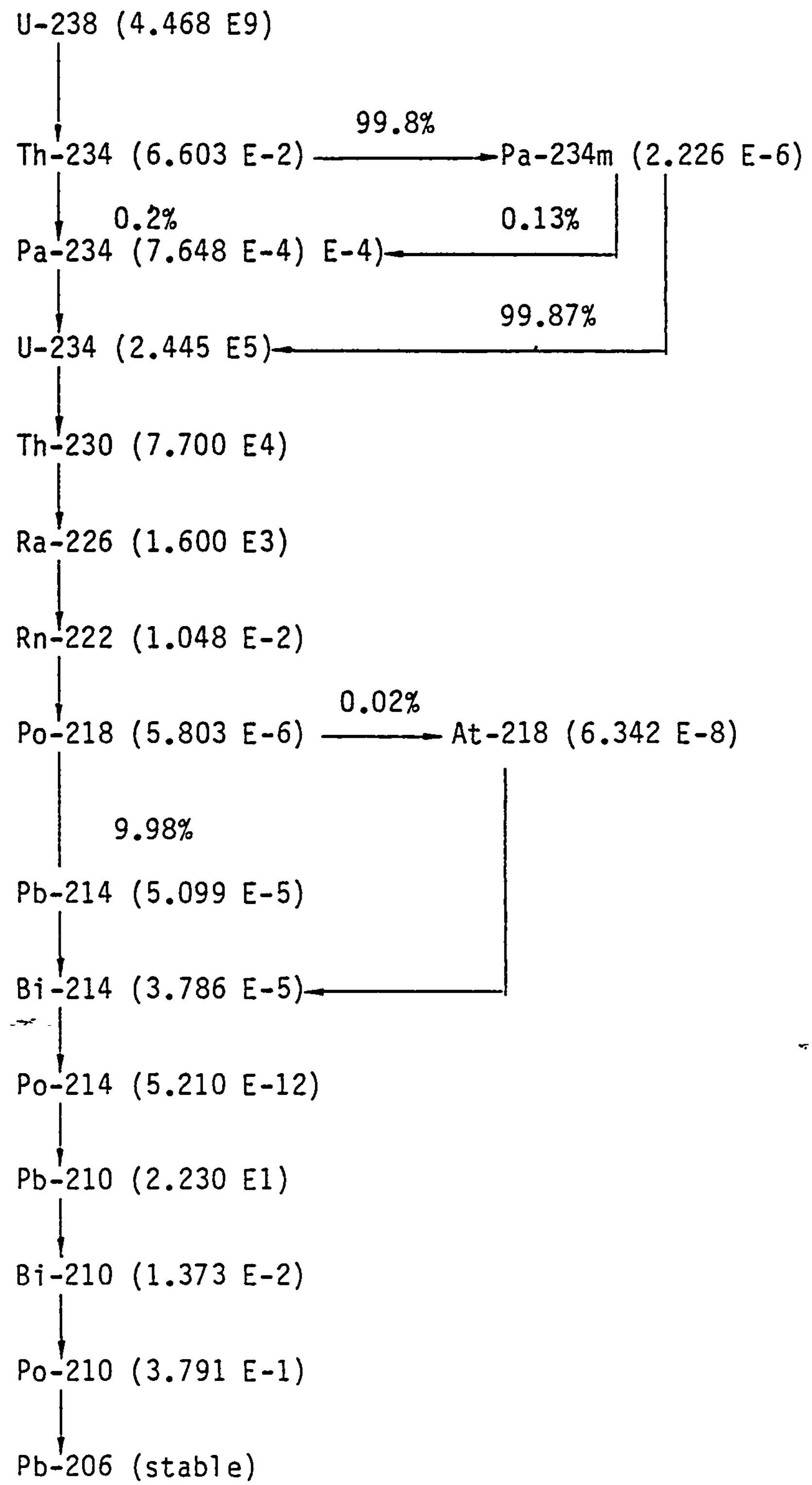


FIGURE 2.3. DECAY SCHEME FOR U-238. Numbers in parenthesis are half-lives in years. Data from ICRP (1979b).

Pu-238 (8.774)

↓

U-234 (2.445 E5)

↓

See Decay Scheme for U-238

FIGURE 2.4. DECAY SCHEME FOR Pu-238. Numbers in parenthesis are half-lives in years. Data from ICRP (1979b).

Pu-239 (2.407 E4)

↓

U-235 (7.038 E8)

↓

See Decay Scheme for U-235

FIGURE 2.5. DECAY SCHEME FOR Pu-239. Numbers in parenthesis are half-lives in years. Data from ICRP (1979b).

If all the decay rates of the daughters are significantly larger (i.e., half-times are shorter) than the parent, $\lambda_j - \lambda_o \approx \lambda_j$ and, after a long time, the exponential terms will all approach zero. Equation (1) then reduces to

$$q_n = q_o. \qquad (2)$$

Equation (2) expresses the activity relationship when the shorter-lived daughters are in equilibrium with the parent. In terms of mass units, the equilibrium relationship is:

$$m_n = \lambda_o m_o / \lambda_n \qquad (3)$$

where m is the mass of the radionuclide.

The actual concentration of a daughter product will be much lower than the equilibrium value if the elapsed time is much smaller than about 5 times the half-life of the daughter. The contaminants were released about 20 to 30 years ago and it is assumed that they consisted only of the specified isotopes of thorium (Th-232 and Th-228), uranium (U-238, U-235, and U-234), and plutonium (Pu-239 and Pu-238). Examinations of the half-lives in Figures 2.1 through 2.5 indicates that only Ra-228 (5.750 years) has a half-life greater than one year and less than six years. Consequently, it is the only daughter product, in addition to Th-228 and U-234, that must be considered. From Equation (1), the concentration of Ra-228 would be about 97 percent of equilibrium after 30 years and it was set to the equilibrium value as a conservative approximation.

The concentrations of the parent radionuclides can be converted from ppm by weight to pCi/kg by the following expression:

$$C_i^s = c_i^s (6.023 \times 10^{23})(1.0 \times 10^{-3}) \ln(2) \, [M_i T_i (3.1536 \times 10^7)(0.037)]^{-1} \qquad (4)$$

where C_i^s is the concentration of Radionuclide i in pCi/kg,

c_i^s is the concentration of Radionuclide i in ppm by weight,

6.023×10^{23} is Avagodro's number (atoms per gram mole),

1.0×10^{-3} converts ppm to g/kg

M_i is the atomic weight of radionuclide i, g/gram mole,

T_i is the half life of radionuclide i, years,

3.1536×10^7 is the number of seconds per year,

0.037 is the number of disintegrations per second equivalent to 1.0 picocurie (pCi).

A secondary radionuclide source is the soil particles resuspended into the air by rototilling and similar gardening activities. The radionuclide concentrations in air resulting from these activities can be estimated as the product of the soil concentration, a soil surface density, and a resuspension factor. The U.S. Nuclear Regulatory Commission (NRC) has recommended a density of 240 kg/m^2 when no other data are available (U.S. NRC, 1977) and this value was used in this report. Sehmel (1980) has summarized resuspension factors applicable to various situations and these are presented in Figure 2.6. As indicated in this figure, a value of about 5.0×10^{-8} m^{-1} seems appropriate for rototilling and other gardening activities. Therefore, the expression for the radionuclide concentrations in air due to resuspension

$$C_i^a = C_i^s \; P \; R \tag{5}$$

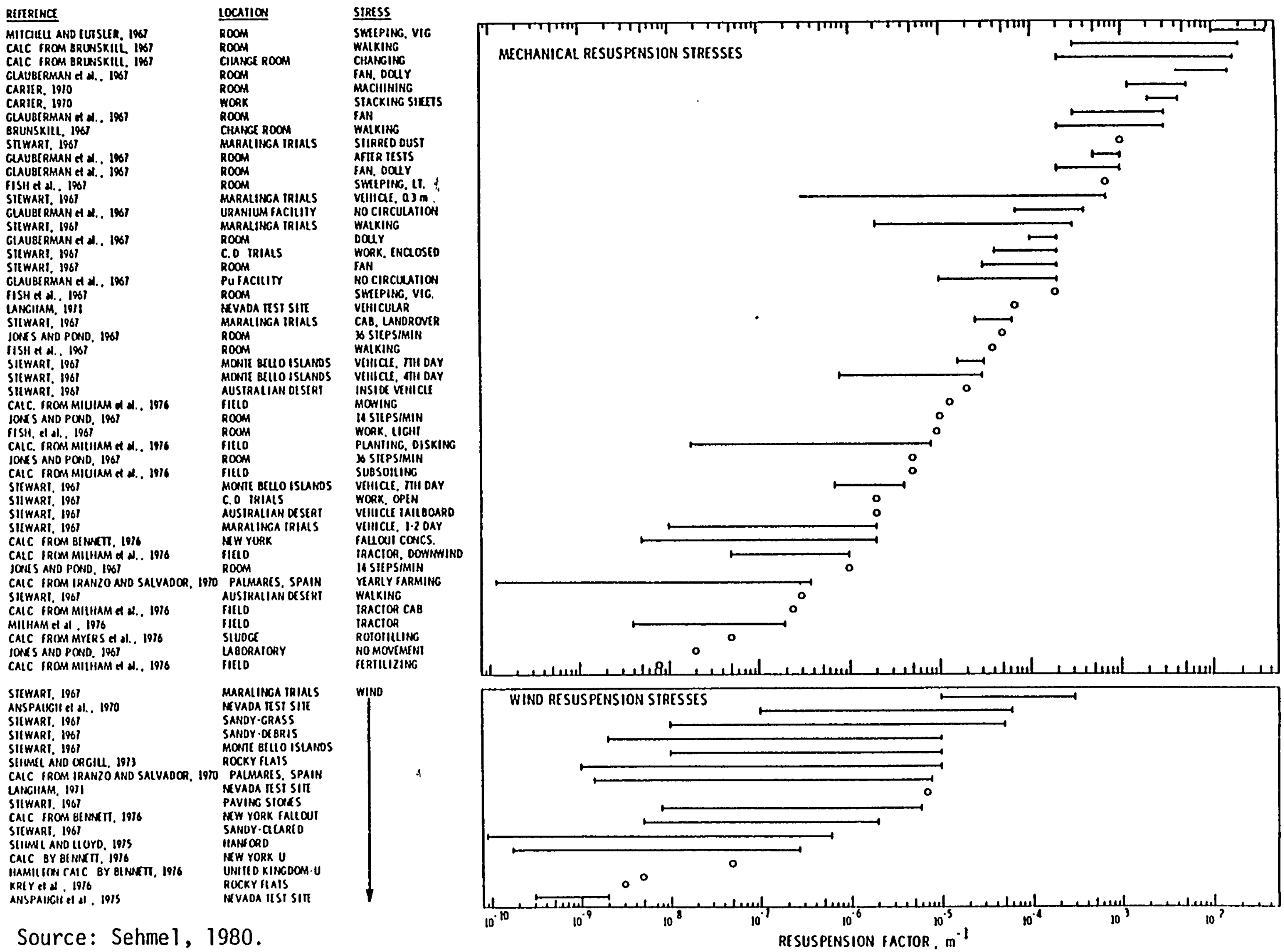
where C_i^a is the concentration of Radionuclide i in air, pCi/m^3

P is the soil surface density, kg/m^2, taken to be 240 (U.S. NRC, 1977)

R is the resuspension factor, m^{-1}, taken to be 5×10^{-8} (Sehmel, 1980).

2.1.2 Exposure Pathways and Doses

The three exposure pathways considered in this analysis were: (1) external (direct exposure) radiation due to standing or walking on the



Source: Sehmel, 1980.

FIGURE 2.6. Resuspension factor ranges from mechanical and wind resuspension stresses.

contaminated ground, (2) internal radiation due to inhalation of soil particles resuspended by rototilling and other such gardening activities, and (3) internal radiation due to ingestion of vegetables grown in the garden. The external exposure is the simplest to consider since it only applies during the time the exposed person is in the garden. Factors have been tabulated for converting surface soil concentrations (the product of the soil concentration and the soil surface density) to external dose rates at a position 1.0 meter above a uniformly contaminated plane (Napier et al., 1980). Factors are listed for both skin and total-body doses but only the total-body dose was considered. The factors include dose contributions from short-lived daughter products but longer-lived daughters need to be considered separately. The factors for the radionuclides considered in this report are listed in Table 2.1. With these factors, the external dose is:

$$D_i^E = C_i^S \; P \; F_i^E \; t_p \tag{6}$$

where D_i^E is the external dose from Radionuclide i, rem,

F_i^E is the dose rate factor for Radionuclide i, rem/hr per pCi/m^2,

and

t_p is the total time spent in the garden during the growing season, hours, assumed to be 343.

With internal exposure due to inhalation and ingestion, the radionuclides taken into the body can be retained for a long time and, consequently, can continue to expose the individual to radiation long after the intake ceases. Inside the body the radionuclides are distributed among the various organs at different rates which depend on the element and its physical and chemical forms. The ICRP has developed factors which incorporate this internal redistribution and the radiological properties of the radionuclides in order to convert intakes to the cumulative radiation doses that would accrue to the organs of reference man (ICRP, 1975) over a period of 50 years following the intake. These factors also include the redistribution and the radiological properties of the daughter products formed after intake. These factors are listed in supplements to ICRP Publication 30 (ICRP, 1979b,

TABLE 2.1. DOSE RATE FACTORS FOR IRRADIATION OF THE TOTAL BODY FROM A UNIFORMLY CONTAMINATED, INFINITE PLANE[a]

Radionuclide	Dose Factor rem/hr per pCi/m^2
Th-232	3.0 E-12(b)
Ra-228	1.2 E-11
Th-228	8.9 E-12
U-235	1.3 E-12
U-238	3.5 E-13
U-234	7.3 E-15
Pu-238	1.3 E-15
Pu-239	7.9 E-16

[a] Source: Napier et al. (1980).
[b] Numbers following E are exponents of 10.

1981, 1982). Factors are also given for weighting the organ doses so they can be appropriately summed to arrive at estimates of an equivalent radiation dose delivered uniformly to the entire body. The uniform body dose can be compared with the external dose and with dose-related health effects. The factors for the radionuclides considered in this report are given in Table 2.2.

With these factors, the internal dose due to inhalation is the product of the air concentrations for each radionuclide, the breathing rate for reference man, the assumed time during which rototilling and other such gardening activities takes place, and the appropriate factor for each radionuclide and each organ. The expression is:

$$D_{ij}^{B} = C_i^{a}\ B\ F_{ij}^{B}\ t_e$$

where D_{ij}^{B} is the 50-year committed dose to Organ j due to inhalation of Radionuclide i, rem,

B is the breathing rate of reference man, m^3/hr, taken to be 1.2 (ICRP, 1975),

F_{ij}^{B} is the dose factor for Radionuclide i to Organ j due to inhalation, rem/pCi,

and

t_e is the assumed time during which rototilling and other such gardening activities takes place, hr, taken to be 86.

It should be noted that dose factors for periods other than 50 years can be calculated using methods presented by the ICRP (1979a). However, the 50-year committed dose is considered to be a reasonable basis for considering dose-limitation criteria (ICRP, 1977).

The internal exposure due to ingestion of vegetables depends on the types of vegetables grown, the redistribution of the radionuclides within the vegetables, and the consumption rates of each type of vegetables. NRC has recommended an expression and parameters for estimating the radionuclide concentration in the edible portions of vegetation (U.S. NRC, 1977). The expression assumes the radionuclide source is a continuous air concentration.

This expression was modified to include soil concentration as a primary source and to incorporate a factor for translocation of radionuclides deposited on leaves to the edible portion (Napier et al., 1980). The resulting expression is

$$C_i^v = \Big\{ 86400\ C_i^a V_{di}\ r\ T_v [1 - \exp(-\lambda_{Ei}\ t_e/24)]/(Y_v\ \lambda_{Ei}) + B_{iv}\ C_i^s \Big\} \exp(-\lambda_i\ t_h) \tag{8}$$

where:

C_i^v is the concentration of Radionuclide i in vegetation, pCi/kg,

V_{di} is the deposition velocity of Radionuclide i, m/sec, taken to be 0.001 (Napier et al., 1980),

r is the fraction of direct deposition retained on plant foliage, dimensionless, taken to be 0.25 (U.S. NRC, 1977),

T_v is the factor for translocation of externally deposited radionuclides to edible parts of plants, dimensionless. For simplicity it is taken to be independent of radionuclide and set to 1.0 for leafy vegetables and other vegetables where the edible portion is above-ground and not covered by a husk, and to 0.1 for all other products (Napier et al., 1980),

λ_{Ei} is the effective environmental removal constant for plants, day^{-1}. $\lambda_{Ei} = \lambda_i + \lambda_w$, where λ_w is the weathering constant, taken to be 0.693/14 days (U.S. NRC, 1977),

Y_v is the plant yield, kg (wet weight)/m^2, taken to be 2.0 (NRC, 1977),

and

t_h is the holdup time between harvest and consumption, days, taken to zero (no holdup).

Values of B_{iv} for the radionuclides considered in this report are given in Table 2.3.

TABLE 2.2. FACTORS FOR CONVERTING RADIONUCLIDE INTAKE BY INGESTION AND INHALATION TO 50-YEAR COMMITTED DOSE EQUIVALENTS TO ORGANS OF REFERENCE MAN[a]

Radionuclide and Mode of Intake	Dose Factor, Sv/Bq[b]								
	Lungs	Bone Surfaces	Red Bone Marrow	Gonads	Breast	LLI[c]	Kidney	Liver	Total[d]
Ra-228E[e]	1.6E-7[g]	5.8E-6	6.5E-7	1.6E-7	1.6E-7	--	--	--	3.3E-7
Ra-228B[f]	7.2E-6	6.5E-6	7.4E-7	--	--	--	--	--	1.2E-6
Th-228E	--	2.4E-6	1.9E-7	--	--	1.3E-7	--	--	1.0E-7
Th-228B	6.9E-4	--	--	--	--	--	--	--	8.3E-5
Th-232E	--	1.9E-5	1.5E-6	--	--	--	--	--	7.4E-7
Th-232B	9.4E-4	5.0E-3	4.0E-4	--	--	--	--	--	3.1E-4
U-234E	--	1.1E-6	7.2E-8	--	--	--	4.7E-7	--	7.1E-8
U-234B	3.0E-4	--	--	--	--	--	--	--	3.6E-5
U-235E	--	1.0E-6	6.8E-8	--	--	5.3E-8	4.3E-7	--	6.8E-8
U-235B	2.8E-4	--	--	--	--	--	--	--	3.3E-5
U-238E	--	1.0E-6	6.8E-8	--	--	--	4.1E-7	--	6.3E-8
U-238B	2.7E-4	--	--	--	--	--	--	--	3.2E-5
Pu-238E	--	1.8E-6	1.5E-7	2.3E-8	--	--	--	4.0E-7	1.0E-7
Pu-238B	3.2E-4	8.3E-4	6.6E-5	--	--	--	--	1.8E-4	8.2E-5
Pu-239E	--	2.1E-6	1.6E-7	2.6E-8	--	--	--	4.4E-7	1.2E-7
Pu-239B	3.2E-4	9.5E-4	7.6E-5	--	--	--	--	2.1E-4	8.9E-5

[a] Source: ICRP (1979b, 1981, 1982).
[b] Units of factors are Sv/Bq (sieverts per becquerel). Multiplication of these units by 3.7 leads to rem/pCi.
[c] LLI is lower large intestine.
[d] The total dose is weighted by the appropriate factors for each organ as specified by the International Commission on Radiological Protection (ICRP, 1977).
[e] E refers to oral ingestion (eating). If more than one solubility class is possible, the most soluble form is assumed for oral ingestion.
[f] B refers to inhalation (breathing). The size of inhaled particles is assumed to be 1.0 micrometer activity mean aerodynamic diameter (AMAD). The least soluble form is assumed for inhalation.
[g] Numbers following E are exponents of 10.

TABLE 2.3. CONCENTRATION RATIOS FOR ROOT UPTAKE[a]

Element	Uptake Ratio pCi/kg plant (wet) per pCi/kg soil (dry)
Ra	1.4E-3
Th	4.2E-3
U	2.5E-3
Pu	2.5E-4

[a] Source: Napier et al. (1980).
[b] Numbers following E are exponents of 10.

The consumption of vegetation is based on diet studies conducted by the U.S. Department of Health, Education and Welfare, Food and Drug Administration (U.S. DHEW, 1980). The average daily consumption of leafy vegetables, including other vegetables where the edible portion is above ground and not covered by a husk, is 0.207 kg and the other garden vegetables is 0.246 kg. These consumption values were multiplied by the corresponding concentrations in vegetation, the estimated time during which the vegetables are consumed, and the appropriate dose factors (Table 2.2) to arrive at 50-year committed doses to each organ and to the total body.
The expression is:

$$D_{ij}^{E} = (E_L\, C_i^{vL} + E_O C_i^{vo})\, F_{ij}^{E}\, t_G \qquad (9)$$

where

D_{ij}^{E} is the 50-year committed dose to Organ j due to ingestion of Radionuclide i, rem,

E_L, E_O are the average daily ingestion rates of leafy and other vegetables, respectively, kg/day, taken to be 0.207 and 0.246 (U.S. DHEW 1980),

C_i^{vL}, C_i^{vo} are the concentrations of Radionuclide i in leafy and other vegetables, respectively, pCi/kg,

F_{ij}^{E} is the dose factor for Radionuclide i to Organ j due to ingestion, rem/pCi, values in Table 2.2,

t_G is the estimated time during which vegetables from the garden are consumed, days, taken to be 120 and 365.

2.2. Mercury Analysis

Potential mercury intakes from ingestion of garden vegetables and fruits were estimated for a variety of exposure scenarios. These scenarios included two levels of mercury in sediment (480 ppm and 240 ppm), three dilution factors expressing the relative degree of mixing between the mercury contaminated sediment and garden soil (0.5, 0.167 and 0.034 sediment to soil ratios), and two levels of home garden utilization (100% and 33% of annual vegetable intake).

Average daily mercury intakes under each of the above scenarios were developed for an adult (fifteen to twenty year old) male. Information on the composition of a typical diet in terms of specific food commodities and the amounts of various commodities consumed per day was derived from U.S. FDA's Total Diet Studies Program (U.S. DHEW, 1980). Data on the composition of the "Adult Total Diet" by food group were derived from Table 2 of the FDA report (see Table 2.4). Intakes (average grams/day) for food groups containing vegetables and fruits were allocated to specific vegetables and fruits in proportion to the amounts given in the Compositing Guide for the South Total Diet Region as shown in Table 2.5 (U.S. DHEW, 1980). The resulting figures, expressed as average daily consumption (grams/day) for each vegetable and fruit comprising the sample diet are shown in Table 2.6. These vegetable and fruit consumption data, together with the plant uptake factor, form the basis for the mercury intake estimates. Certain fruits and vegetable products included in the total diet such as citrus and orchard fruit and grain based products (e.g., wheat flour, commercial cereals, breads, and pastas) were not included in the analysis since it is unlikely they would be grown in a home garden.

Given information on soil mercury levels and the amounts and types of vegetables comprising a typical adult diet in the region it is necessary to relate mercury concentrations present in the soil to those anticipated in garden produce. A review of the literature indicated that there is no readily available model suitable for the purposes of this analysis. Therefore a very simple model in which a plant uptake factor (i.e., the ratio of the concentration of mercury present in the plant to that in soil) is applied to the various constituents of the diet to estimate the mercury content of each commodity.

TABLE 2.4. COMPOSITION (DAILY BASIS) OF FY77 ADULT TOTAL DIET BY FOOD CLASS AND WEIGHT[a,b]

	Food Group (Composite)	Average grams/day	% (by weight) of Total Diet
I.	Dairy	753	25.5
II.	Meat, fish, and poultry	262	8.4
III.	Grains and cereals	418	15.0
IV.	Potatoes	159	6.0
V.	Leafy vegetables	58	2.0
VI.	Legume vegetables	74	2.5
VII.	Root vegetables	32	1.4
VIII.	Garden fruits	75	3.2
IX.	Fruits	219	7.5
X.	Oils and fats	73	3.0
XI.	Sugars and adjuncts	81	3.0
XII.	Beverages (including water)	671	22.5
	Total	2875	100.0

[a] Source: U.S. DHEW, 1980.
[b] Based on adult male aged 15-20.

TABLE 2.5. COMPLIANCE PROGRAM REPORT OF FINDINGS[a]
FY 77 TOTAL DIET STUDIES - ADULT (7320.73)
ATTACHMENT F SHOPPING AND COMPOSITION GUIDE
SOUTH TOTAL DIET REGION

Composite Number	Food Group	Comodity To Be Collected	14 Day Consumotion (grams)
I	Dairy Products	Milk, fresh fluid	3,048
		Evaporated milk	243
		Nonfat dry milk	34
		Ice cream	252
		Cottage cheese	45
		Processed cheese, american	34
		Natural cheese	57
		Butter	34
		Skim milk	144
		Ice milk	83
		Buttermilk	192
		TOTAL	4,166
II	Meat, Fish and Poultry	Roast beef, chuck (bone in)*	294
		Ground beef, hamburger*	359
		Pork chops*	232
		Bacon*	108
		Chicken, whole eviserated, fresh or frozen*	472
		Fish fillet, fresh or frozen*	222
		Fish, canned, tuna or salmon	85
		Luncheon meat	284
		Frankfurters	170
		Beef liver*	40
		Eggs, large	700
		Cured ham, bone in, not canned*	161
		Round steak, beef with bone in*	384
		Veal, chops or cutlets*	33
		Roast lamb*	0
		Raw shrimp, fresh or frozen*	45
		TOTAL	3,639
III	Grai s and Cereals	Flour, general purpose	128
		Flour, self-rising	284
		Pancake mix	43
		Corn flakes	71
		Wheat cereal, ready-to-eat	28
		Rice flakes or puffed rice	14
		Oatmeal	71
		Rice	123
		Cornmeal	184
		Corn Grits	43
		Macaroni, elbow	57
		White bread, enriched	992
		Whole wheat bread	14
		Rolls, sweet	85
		Snack items (pretzels, corn chips, crackers, etc.)	128
		Cookies, plain w/o nuts or chocolate	213
		Buns, frankfurter or hamburger	71
		Pie, 8-inch apple, double crust, pie crust only	113
		Cake mix	57
		Wheat cereal, eaten cooked	0
		Corn, whole kernel, canned	85
		Corn, whole kernel, frozen (not frozen corn on cob)*	56
		TOTAL	2,365
IV	Potatoes	White potatoes, baked*	176
		White potatoes, boiled*	1,298
		White potatoes, fried*	491
		Potato chips	85
		Frozen french fries*	85
		Dehydrated potatoes	28
		Sweet potatoes or yams, canned	24
		Sweet potatoes or yams, fresh*	35
		TOTAL	2,222

Composite Number	Food Group	Commodity To Be Collected	14 Day Consumption (grams)
V	Leafy Vegetables	Spinach, collards or mustard greens, fresh or frozen*	438
		Celery*	288
		Lettuce*	1,374
		Cabbage, raw*	746
		Cabbage, cooked*	198
		Broccoli, fresh or frozen*	196
		Asparagus, canned	62
		Asparagus, fresh or frozen*	140
		Cauliflower, fresh or frozen*	0
		TOTAL	3,442
VI	Legume Vegetables	Peas, canned	538
		Peas, frozen*	264
		Green beans, canned	480
		Green beans, frozen*	534
		Beans w/pork, canned	2,608
		Lima beans, frozen*	122
		TOTAL	4,546
VII	Root Vegetables	Carrots, fresh w/o tops*	1,080
		Mature onions, dry, raw*	284
		Mature onions, dry, boiled*	1,148
		Beets w/o tops, canned	460
		Green onions*	268
		TOTAL	3,240
VIII	Garden Fruits	Green peppers, fresh*	84
		Tomatoes, fresh*	1,512
		Tomatoes, canned	454
		Cucumbers, fresh*	408
		Catsup	568
		Pickles, dill or sweet	406
		Vegetable soup, canned condensed (undiluted)	510
		Tomato soup, canned, condensed, (undiluted)	56
		TOTAL	3,998
IX	Fruits	Fruit filling from pie (see Composite III)	567
		Oranges, fresh*	212
		Citrus juice, frozen concentrate, undiluted	89
		Bananas	235
		Raisins	0
		Peaches, fresh or canned*	159
		Apples, fresh*	404
		Strawberries, fresh or frozen*	45
		Citrus juice, canned	154
		Citrus juice, fresh	83
		Prunes w/o pits	28
		Grapefruit, fresh*	194
		Fruit juice, non-citrus, canned	148
		Apricots, w/o pits, canned	28
		Cherries, w/o pits, fresh or canned*	26
		Grapes, fresh*	24
		Pears, fresh or canned*	53
		Pineapple, fresh or canned*	26
		Rhubarb, fresh, frozen or canned*	0
		Watermelon, fresh or frozen*	370
		Cantaloupe, fresh or frozen*	59
		Fruit cocktail	85
		TOTAL	2,989
X	Oils and Fats	Salad dressing, mayonnaise	224
		Salad dressing, french	64
		Salad dressing, others (excluding salad oils)	180
		Shortening (hydrogenated)	794
		Peanut butter	284
		Margarine	567
		TOTAL	2,113
XI	Sugars and Adjuncts	White sugar	1,304
		Jelly	170
		Pudding mix	57
		Syrup, blended cane-maple	240
		Jam	57
		Candy bars	170
		Baking powder	28
		Salt, non-iodized	113
		Vinegar	120
		TOTAL	2,259

Composite Number	Food Group	Commodity To Be Collected	14 Day Consumption (grams)
XII	Beverages	Tea leaves (brewed)	11 (fi e)
		Coffee, ground (brewed)	68 (filtrate)
		Cocoa, plain, not drink powder	11
		Cola soft drink	552
		Non-cola soft drink	144
		Coffee, instant	11
		Drinking water	3,400
		TOTAL	4,113

*The food is first sent to a contracted dietician kitchen (currently the Home Economics Department of St. Mary's College, Leavenworth, Kansas for appropriate cooking or other preparation normally employed prior to consumption. Other food items did not need preparation prior to inclusion to the composite.

[a]Source: U.S. DHEW, 1980.

TABLE 2.6. GARDEN VEGETABLES - FDA TOTAL DIET STUDIES, SOUTHERN U.S.[a]

	FDA Food Group	Commodity	Average Daily Consumption, Grams[b]
III.	Grains and Cereals	Corn, whole kernel, canned	12.4
		Corn, whole kernel, canned	8.2
			Total = 20.6
IV.	Potatoes	White potatoes, baked	12.6
		White potatoes, boiled	92.8
		White potatoes, fried	35.1
		Potato Chips	6.1
		Frozen french fries	6.1
		Dehydrated potatoes	2.0
		Sweet potatoes or yams, canned	1.7
		Sweet potatoes or yams, fresh	2.5
			Total = 159
V.	Leafy Vegetables	Spinach, collards or mustard greens, fresh or frozen	7.4
		Celery	4.9
		Lettuce	23.2
		Cabbage, raw	12.6
		Cabbage, cooked	3.3
		Broccoli, fresh or frozen	3.3
		Asparagus, canned	1.0
		Asparagus, fresh or frozen	2.4
			Total = 58
VI.	Legume Vegetables	Peas, canned	8.8
		Peas, frozen	4.3
		Green beans, canned	7.8
		Green beans, frozen	8.7
		Beans w/pork, canned	42.4
		Lima beans, frozen	2.0
			Total = 74
VII.	Root Vegetables	Carrot, fresh or frozen	10.7
		Mature onions dry, raw	2.9
		Mature onions dry, boiled	11.3
		Beets, canned	4.5
		Green onions	2.6
			Total = 32

TABLE 2.6. GARDEN VEGETABLES - FDA TOTAL DIET STUDIES, SOUTHERN U.S.[a] (CONTINUED)

FDA Food Group		Commodity	Average Daily Consumption, Grams[b]
VIII.	Garden Fruits	Green peppers, fresh	1.6
		Tomatoes, fresh	28.4
		Tomatoes, canned	8.5
		Cucumbers, fresh	7.6
		Catsup	10.7
		Pickles, dill or sweet	7.6
		Vegetable soup, canned condensed	9.6
		Tomato soup, canned condensed	1.0
			Total = 75
			Grand Total = 418.6
IX.	Fruits	Strawberries, fresh or frozen	3.3
		Watermelon, fresh or frozen	27.1
		Cantaloupe, fresh or frozen	4.3
			Total = 34.7
			Grand Total = 453.3

[a] Source: FY 77 Total Diet Studies - Adult (U.S. DHEW, 1980).
[b] Based on 14 day dietary consumption of adult (teenage) male.

Although a literature search identified approximately 20 references dealing with mercury uptake in plants, only a few of the studies examined mercury uptake in garden crops under conditions similar to those under consideration in this analysis. Since there was considerable variability in estimated plant uptake rates, both within and between studies, and because there was a definite decrease in plant uptake ratios as soil mercury levels increased, it was clearly inappropriate to select a single value to represent plant/soil ratios over the wide range of soil concentrations included in the pathways analysis. Consequently paired data on mercury levels in plants and the soil on which they were grown were gathered from several studies and a regression line was fitted to these data. Data used to compute the regression line are given in Table 2.7. Where necessary, mercury concentrations in plants were converted to a wet weight basis using moisture values obtained from the U.S. Department of Agriculture (USDA, 1963). Soil and plant data were then transformed to their natural logarithms and a regression line was fitted to the transformed data using the least-squares method. The resulting equation (after taking antilogs) was:

$$\hat{Y} = 0.010116 \cdot \left[(S)^{0.531800}\right]$$

where

S = soil mercury concentration

$\hat{Y}$ = predicted (wet weight) mercury level in vegetation

$R = 0.975$

The regression equation above was then used to predict the mercury content of plants for the following soil concentrations of interest:

Level of Mercury in Sediment	Dilution Factor	Resulting Soil Mercury Level
480 ppm	0.5	240 ppm
480 ppm	0.167	80.2 ppm
480 ppm	0.034	16.3 ppm
240 ppm	0.5	120 ppm
240 ppm	0.167	40.1 ppm
240 ppm	0.134	8.2 ppm

TABLE 2.7. SUMMARY OF MERCURY UPTAKE STUDIES WITH SOIL CONCENTRATIONS AND COMPUTED ESTIMATES FOR WET WEIGHT PLANT CONCENTRATIONS AND PLANT/SOIL UPTAKE RATIOS

Investigator	Soil Hg, μg/g	Wet Weight Plant Hg, μg/g	Plant/Soil Ratio
Maclean, 1974	0.080	0.00705	0.08813
"	5.250	0.00825	0.00157
John, 1972	4.000	0.00255	0.00064
"	20.000	0.00675	0.00034
Maclean, 1974	0.575	0.00540	0.00939
"	3.127	0.00555	0.00177
"	27.543	0.04755	0.000002
"	0.150	0.00390	0.02600
"	1.640	0.02595	0.01582
"	0.090	0.00435	0.04833
"	7.130	0.01545	0.00217
Cappon, 1981	0.117	0.00075	0.00641
"	0.326	0.00615	0.01886
"	0.117	0.00045	0.00385
"	0.326	0.00495	0.01518
Vaughan, 1975	0.400	0.00225	0.00562
"	10.000	0.17850	0.01785
"	10.000	0.00765	0.00077
"	97.000	0.46000	0.00472
Lindberg et al., 1979	2.300	0.24500	0.10652
Estes et al., 1973	455.000	0.25200	0.00055
Saha et al., 1970	0.070	0.01020	0.14571
"	1.700	0.09350	0.00550
"	3.500	0.19550	0.05586

Predicted plant/soil uptake ratios are shown below:

Soil Mercury Level	Predicted Uptake Ratio
240 ppm	0.00078
80.2 ppm	0.00130
16.3 ppm	0.00274
120 ppm	0.00108
40.1 ppm	0.00180
8.2 ppm	0.00378

The expected mercury content of each food group was calculated as the product of the concentration of mercury in sediment, the dilution factor, and the predicted uptake ratio based on the regression equation.

A plot of the data distribution and regression line are shown in Figure 2.7. The natural log transformation of both the soil and plant concentrations resulted in a relatively good fit accounting for 95 percent of the variability. Patterns for linear and linear-log plots were not apparent. This situation points strongly to the lack of understanding of mercury behavior in plant uptake particularly when high soil concentrations occur. More understanding is needed with respect to soil types, species effects, and the mode of vegetable contamination including root uptake, direct adsorption, and gaseous mercury uptake.

It also became apparent in the analysis that plant wet weight regressions for mercury concentrations were much better than for dry weight relationships.

Having estimated the expected mercury content of vegetation under each scenario, the resulting daily mercury intake from garden produce was then estimated by multiplying the expected mercury content of each food group by the average daily consumption for each food group and summing over all groups. The terms included in the model are shown below.

Mercury Concentration in Sediment		Soil Dilution Factor		Plant Uptake Ratio for Specific Concentrations[a,b]		Average Daily Consumotion		Percentage of Vegetables From Home Garden
480 or 240 ppm	X	0.5, 0.167, or 0.034	X	240 - 0.00078	X	453.3 g/day	X	100% or 33%
				80.2 - 0.00130				
				16.3 - 0.00274				
				120 - 0.00108				
				40.1 - 0.00180				
				8.2 - 0.00378				

[a] Based on regression equation described in text (Section 2.2).

[b] (480)(0.5) = 240; (480)(0.0167) = 80.2; etc.

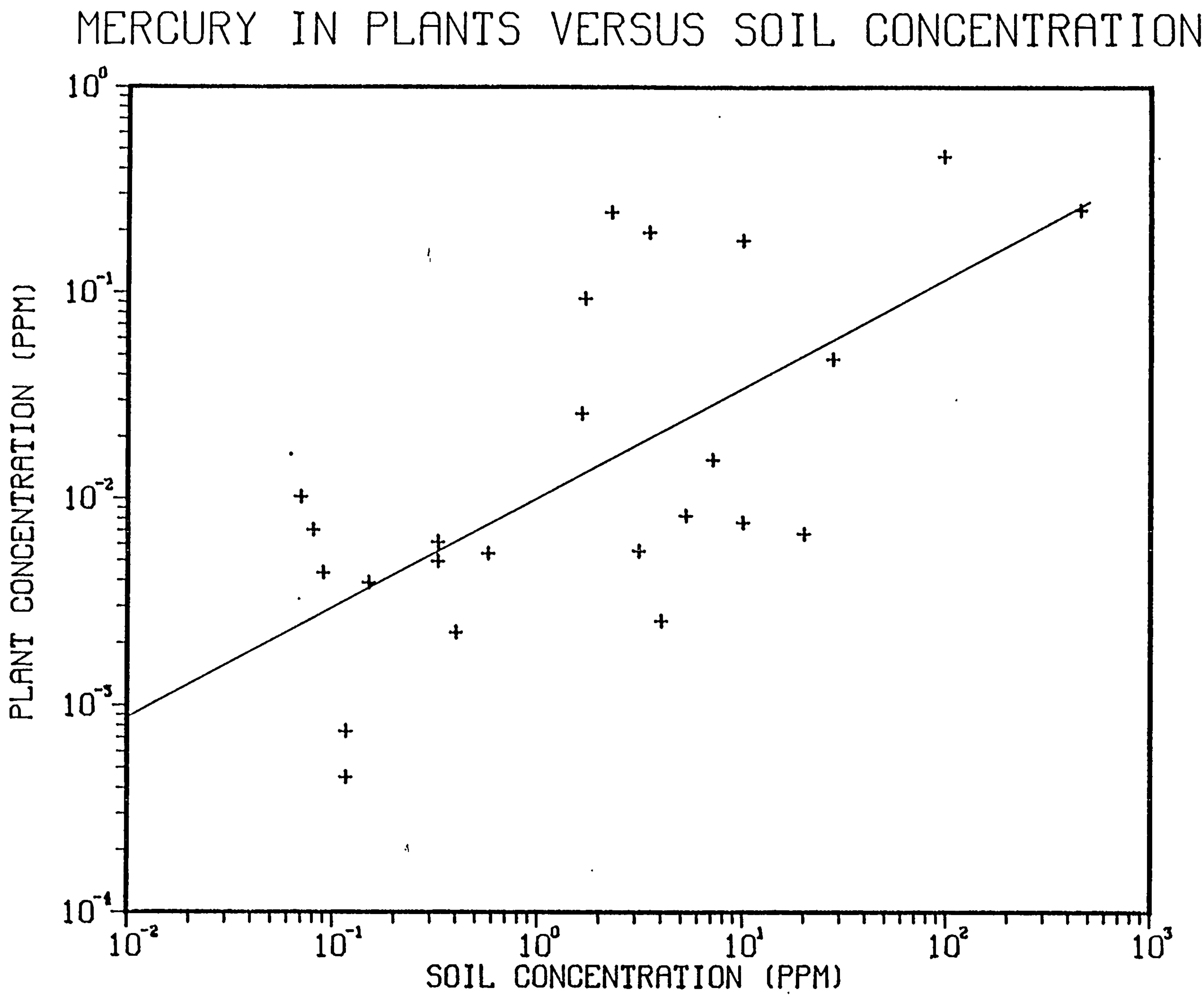


FIGURE 2.7. REGRESSION OF WEIGHT WET PL^"T MERCURY CONCENTRATIONS VERSUS SOIL MERCURY CONCENT. .IONS.

Tables 2.8 to 2.11 present the results obtained for mercury under the various exposure scenarios described above.

2.3 PCB Analysis

Potential PCB intakes from ingestion of garden vegetables and fruits were estimated for various exposure scenarios. These scenarios included two levels of PCBs in the sediment (0.6 ppm and 0.3 ppm), three dilution factors expressing the degree of mixing between the PCB contaminated sediment and garden soil (0.5, 0.167, and 0.034 sediment to soil ratios), and two levels of home garden utilization (100% and 33% of annual vegetable intake supplied by the garden).

Average daily PCB intakes under each of the above scenarios were developed for an adult male fifteen to twenty years old. Information on the composition of a typical diet, namely the food commodities which account for a significant portion of the diet and the amounts of various commodities consumed per day was obtained from U.S. FDA's Total Diet Studies Program (U.S. DHEW, 1980). Data on the composition of the "Adult Total Diet" by food group was derived from Table 2 of the FDA report (see Table 2.4). Intakes (average grams/day) for FDA food groups containing vegetables and fruits were allocated to specific vegetables and fruits in proportion to the amounts given in the Compositing Guide for the South Total Diet Region as shown in Table 2.5 (U.S. DHEW, 1980). The resulting figures, expressed as average daily consumption (grams/day) for each vegetable and fruit comprising the sample diet, together with the plant uptake factor, form the basis for the PCB intake estimates. It should be noted that certain fruit and vegetable products included in FDA's Total Diet Studies were not included in the analysis since it is unlikely they would be grown in a home garden.

Given information on PCB levels in garden soil and the amounts and types of fruits and vegetables comprising the typical adult diet in the region, it is necessary to relate PCB concentrations present in soil to those anticipated in garden produce. A transport model suitable for purposes of this analysis could not be located. Therefore, a simple model was utilized in

TABLE 2.8. PREDICTED MERCURY INTAKE FROM GARDEN VEGETABLES AND FRUITS GROWN ON SOIL CONTAINING 480 PPM MERCURY: CASE 1 - 100 PERCENT OF ANNUAL VEGETABLE INTAKE FROM GARDEN

Soil Dilution Factor	Plant Uptake Ratio[a]	Food Group	Average Daily Consumption, grams[b,c]	Daily Dietary Intake, μg/day
0.5	0.00078	Corn	20.6	3.8
0.5	0.00078	Potatoes/potato products	159	29.7
0.5	0.00078	Leafy vegetables	58	10.8
0.5	0.00078	Legume vegetables	74	13.8
0.5	0.00078	Root vegetables	32	6.0
0.5	0.00078	Garden fruits[d]	38.1	7.1
0.5	0.00078	Tomatoes[e]	36.9	6.9
0.5	0.00078	Other fruits[f]	34.7	6.5
0.5	0.00078	All vegetables[g]	453.3	84.5
0.167	0.00130	Corn	20.6	2.1
0.167	0.00130	Potatoes/potato products	159	16.5
0.167	0.00130	Leafy vegetables	58	6.0
0.167	0.00130	Legume vegetables	74	7.7
0.167	0.00130	Root vegetables	32	3.3
0.167	0.00130	Garden fruits[d]	38.1	4.0
0.167	0.00130	Tomatoes[e]	36.9	3.8
0.167	0.00130	Other fruits[f]	34.7	3.6
0.167	0.00130	All vegetables[g]	453.3	47.2
0.034	0.00274	Corn	20.6	0.9
0.034	0.00274	Potatoes/potato products	159	7.1
0.034	0.00274	Leafy vegetables	58	2.6
0.034	0.00274	Legume vegetables	74	3.3
0.034	0.00274	Root vegetables	32	1.4
0.034	0.00274	Garden fruits[d]	38.1	1.7
0.034	0.00274	Tomatoes[e]	36.9	1.7
0.034	0.00274	Other fruits[f]	34.7	1.6
0.034	0.00274	All vegetables[g]	453.3	20.2

[a] See text for description of method by which uptake factors were derived (Section 2.2).
[b] Based on FDA Total Diet Studies - Adult Male, Southern, U.S.
[c] Source: U.S. DHEW, 1980.
[d] Includes commodities shown under "Garden Fruits", Table 2.6 except tomatoes.
[e] Includes fresh and canned tomatoes.
[f] Includes commodities shown under Other Fruits, Table 2.6.
[g] Includes all vegetable commodities listed in Table 2.6.

TABLE 2.9. PREDICTED MERCURY INTAKE FROM GARDEN VEGETABLES AND FRUITS GROWN IN SOIL CONTAINING 480 PPM MERCURY: CASE 2 - 33 PERCENT OF ANNUAL VEGETABLE INTAKE FROM GARDEN

Soil Dilution Factor	Plant Uptake Ratio[a]	Food Group	Average Daily Consumption, grams[b,c]	Daily Dietary Intake, µg/day
0.5	0.00078	Corn	20.6	1.2
0.5	0.00078	Potatoes/potato products	159	9.8
0.5	0.00078	Leafy vegetables	58	3.6
0.5	0.00078	Legume vegetables	74	4.6
0.5	0.00078	Root vegetables	32	2.0
0.5	0.00078	Garden fruits[d]	38.1	2.4
0.5	0.00078	Tomatoes[e]	36.9	2.3
0.5	0.00078	Other fruits[f]	34.7	2.1
0.5	0.00078	All vegetables[g]	453.3	27.8
0.167	0.00130	Corn	20.6	0.7
0.167	0.00130	Potatoes/potato products	159	5.4
0.167	0.00130	Leafy vegetables	58	2.0
0.167	0.00130	Legume vegetables	74	2.5
0.167	0.00130	Root vegetables	32	1.1
0.167	0.00130	Garden fruits[d]	38.1	1.3
0.167	0.00130	Tomatoes[e]	36.9	1.3
0.167	0.00130	Other fruits[f]	34.7	1.2
0.167	0.00130	All vegetables[g]	453.3	15.5
0.034	0.00274	Corn	20.6	0.3
0.034	0.00274	Potatoes/potato products	159	2.3
0.034	0.00274	Leafy vegetables	58	0.9
0.034	0.00274	Legume vegetables	74	1.1
0.034	0.00274	Root vegetables	32	0.5
0.034	0.00274	Garden fruits[d]	38.1	0.6
0.034	0.00274	Tomatoes[e]	36.9	0.3
0.034	0.00274	Other fruits[f]	34.7	0.5
0.034	0.00274	All vegetables[g]	453.3	6.6

[a] See test for description of method by which uptake factors were derived (Section 2.2).
[b] Based on FDA Total Diet Studies - Adult Male, Southern, U.S.
[c] Source: U.S. DHEW, 1980.
[d] Includes commodities shown under "Garden Fruits", Table 2.6 except tomatoes.
[e] Includes fresh and canned tomatoes.
[f] Includes commodities shown under "Other Fruits", Table 2.6.
[g] Includes all vegetable commodities listed in Table 2.6.

TABLE 2.10. PREDICTED MERCURY INTAKE FROM GARDEN VEGETABLES AND FRUITS GROWN ON SOIL CONTAINING 240 PPM MERCURY: CASE 1 - 100 PERCENT OF ANNUAL VEGETABLE INTAKE FROM GARDEN

Soil Dilution Factor	Plant Uptake Ratio[a]	Food Group	Average Daily Consumption, grams[b,c]	Daily Dietary Intake, μg/day
0.5	0.00108	Corn	20.6	2.7
0.5	0.00108	Potatoes/potato products	159	20.5
0.5	0.00108	Leafy vegetables	58	7.5
0.5	0.00108	Legume vegetables	74	9.5
0.5	0.00108	Root vegetables	32	4.1
0.5	0.00108	Garden fruits[d]	38.1	4.9
0.5	0.00108	Tomatoes[e]	36.9	4.8
0.5	0.00108	Other fruits[f]	34.7	4.5
0.5	0.00108	All vegetables[g]	453.3	58.5
0.167	0.00180	Corn	20.6	1.5
0.167	0.00180	Potatoes/potato products	159	11.5
0.167	0.00180	Leafy vegetables	58	4.2
0.167	0.00180	Legume vegetables	74	5.3
0.167	0.00180	Root vegetables	32	2.3
0.167	0.00180	Garden fruits[d]	38.1	2.7
0.167	0.00180	Tomatoes[e]	36.9	2.7
0.167	0.00180	Other fruits[f]	34.7	2.5
0.167	0.00180	All vegetables[g]	453.3	32.7
0.034	0.00378	Corn	20.6	0.6
0.034	0.00378	Potatoes/potato products	159	4.9
0.034	0.00378	Leafy vegetables	58	1.8
0.034	0.00378	Legume vegetables	74	2.3
0.034	0.00378	Root vegetables	32	1.0
0.034	0.00378	Garden fruits[d]	38.1	1.2
0.034	0.00378	Tomatoes[e]	36.9	1.1
0.034	0.00378	Other fruits[f]	34.7	1.1
0.034	0.00378	All vegetables[g]	453.3	14.0

a See text for description of method by which uptake factors were derived (Section 2.2).
b Based on FDA Total Diet Studies - Adult Male, Southern, U.S.
c Source: U.S. DHEW, 1980.
d Includes commodities shown under "Garden Fruits", Table 2.6 except tomatoes.
e Includes fresh and canned tomatoes.
f Includes commodities shown under "Other Fruits", Table 2.6.
g Includes all vegetable commodities listed in Table 2.6.

TABLE 2.11. PREDICTED MERCURY INTAKE FROM GARDEN VEGETABLES AND FRUITS GROWN ON SOIL CONTAINING 240 PPM MERCURY: CASE 2 - 33 PERCENT OF ANNUAL VEGETABLE INTAKE FROM GARDEN

Soil Dilution Factor	Plant Uptake Ratio[a]	Food Group	Average Daily Consumption, grams[b,c]	Daily Dietary Intake, μg/day
0.5	0.00108	Corn	20.6	0.9
0.5	0.00108	Potatoes/potato products	159	6.7
0.5	0.00108	Leafy vegetables	58	2.5
0.5	0.00108	Legume vegetables	74	3.1
0.5	0.00108	Root vegetables	32	1.4
0.5	0.00108	Garden fruits[d]	38.1	1.6
0.5	0.00108	Tomatoes[e]	36.9	1.6
0.5	0.00108	Other fruits[f]	34.7	1.5
0.5	0.00108	All vegetables[g]	453.3	19.2
0.167	0.00180	Corn	20.6	0.5
0.167	0.00180	Potatoes/potato products	159	3.8
0.167	0.00180	Leafy vegetables	58	1.4
0.167	0.00180	Legume vegetables	74	1.8
0.167	0.00180	Root vegetables	32	0.8
0.167	0.00180	Garden fruits[d]	38.1	0.9
0.167	0.00180	Tomatoes[e]	36.9	0.9
0.167	0.00180	Other fruits[f]	34.7	0.8
0.167	0.00180	All vegetables[g]	453.3	10.7
0.034	0.00378	Corn	20.6	0.2
0.034	0.00378	Potatoes/potato products	159	1.6
0.034	0.00378	Leafy vegetables	58	0.6
0.034	0.00378	Legume vegetables	74	0.8
0.034	0.00378	Root vegetables	32	0.3
0.034	0.00378	Garden fruits[d]	38.1	0.4
0.034	0.00378	Tomatoes[e]	36.9	0.4
0.034	0.00378	Other fruits[f]	34.7	0.4
0.034	0.00378	All vegetables[g]	453.3	4.6

[a] See text for description of method by which uptake factors were derived (Section 2.2).
[b] Based on FDA Total Diet Studies - Adult Male, Southern, U.S.
[c] Source: U.S. DHEW, 1980.
[d] Includes commodities shown under "Garden Fruits", Table 2.6 except tomatoes.
[e] Includes fresh and canned tomatoes.
[f] Includes commodities shown under "Other Fruits", Table 2.6.
[g] Includes all vegetable commodities listed in Table 2.6.

which a plant uptake factor (i.e., the ratio of concentration of PCB present in the plant to that in the soil) is applied to the various constituents of the diet to estimate the PCB content of each commodity.

Plant uptake factors for PCBs were selected as appropriate to the vegetable and fruit commodities included in the diet (see Section 2.3.1., Volume 1). The highest factor, 0.025, was used for root crops such as potatoes, carrots, beets, onions, etc. This value represents the midpoint of the range of uptake factors reported for highly chlorinated PCBs by Moza et al. (1979) and Iwata et al. (1974) from studies on carrots and beets. A value of 0.02 was used for leafy vegetables since this was the midpoint of the range reported for assorted plant tops by Strek et al. (1981). The uptake value used for legume vegetables, 0.003, was the midpoint of the range reported for soybeans by Fries and Marrow (1981). For grains and cereals (corn) the uptake factor used was 0.001, the value reported by Strek et al. (1981) in corn tops.

Having estimated the expected PCB content of each garden vegetable and fruit in the sample diet, the resulting daily PCB intake from garden produce was then estimated by multiplying the expected PCB content of each food group by the average daily consumption for each food group followed by summation over all groups. The terms included in the model are shown below:

PCB Concentration in Sediment		Soil Dilution Factor		Plant Uptake Factor		Average Daily Consumption		Percentage of Vegetables From Home Garden
0.6 or 0.3 ppm	X	0.5, 0.167, or 0.034	X	0.001 - corn 0.002 - fruits and garden fruits 0.003 - legumes 0.020 - leafy vegetables 0.025 - root vegetables	X	g/day for each commodity	X	100% or 33%

Tables 2.12 to 2.15 present the results obtained for PCBs under the various exposure scenarios described above.

TABLE 2.12. PREDICTED PCB INTAKE FROM GARDEN VEGETABLES AND FRUITS GROWN ON SOIL CONTAINING 0.6 PPM PCB: CASE I - 100 PERCENT OF ANNUAL VEGETABLE INTAKE FROM GARDEN

Soil Dilution Factor	Plant Uptake Factor[a]	Food Group	Average Daily Consumption (grams)[b,c]	Daily Dietary Intake, ng/day
0.5	0.001	Corn	20.6	6
0.5	0.025	Potatoes/potato products	159	1193
0.5	0.020	Leafy vegetables	58	348
0.5	0.003	Legume vegetables	74	67
0.5	0.025	Root vegetables	32	240
0.5	0.002	Garden fruits[d]	38.1	23
0.5	0.002	Tomatoes[e]	36.9	22
0.5	0.002	Other fruits[f]	34.7	21
0.5	--	All vegetables[g]	453.3	1920
0.167	0.001	Corn	20.6	2
0.167	0.025	Potatoes/potato products	159	398
0.167	0.020	Leafy vegetables	58	116
0.167	0.003	Legume vegetables	74	22
0.167	0.025	Root vegetables	32	80
0.167	0.002	Garden fruits[d]	38.1	8
0.167	0.002	Tomatoes[e]	36.9	7
0.167	0.002	Other fruits[f]	34.7	7
0.167	--	All vegetables[g]	453.3	640
0.034	0.001	Corn	20.6	0.4
0.034	0.025	Potatoes/potato products	159	81
0.034	0.020	Leafy vegetables	58	24
0.034	0.003	Legume vegetables	74	5
0.034	0.025	Root vegetables	32	16
0.034	0.002	Garden fruits[d]	38.1	2
0.034	0.002	Tomatoes[e]	36.9	1.5
0.034	0.002	Other fruits[f]	34.7	1.4
0.034	--	All vegetables[g]	453.3	132

[a] See text for description of method by which uptake factors were derived (Section 2.3).
[b] Based on FDA Total Diet Studies - Adult Male, Southern, U.S.
[c] Source: U.S. DHEW, 1980.
[d] Includes commodities shown under "Garden Fruits", Table 2.6 except tomatoes.
[e] Includes fresh and canned tomatoes.
[f] Includes commodities shown under "Other Fruits", Table 2.6.
[g] Includes all vegetable commodities listed in Table 2.6.

TABLE 2.13. PREDICTED PCB INTAKE FROM GARDEN VEGETABLES AND FRUITS GROWN ON SOIL CONTAINING 0.6 PPM PCB: CASE 2 - 33 PERCENT OF ANNUAL VEGETABLE INTAKE FROM GARDEN

Soil Dilution Factor	Plant Uptake Factor[a]	Food Group	Average Daily Consumption (grams)[b,c]		Daily Dietary Intake, ng/day	
0.5	0.001	Corn	20.6		·2	
0.5	0.025	Potatoes/potato products	159		392	
0.5	0.020	Leafy vegetables	58		114	
0.5	0.003	Legume vegetables	74		22	
0.5	0.025	Root vegetables	32		79	
0.5	0.002	Garden fruits[d]	38.1		8	
0.5	0.002	Tomatoes[e]	36.9		7	
0.5	0.002	Other fruits[f]	34.7		7	
0.5	--	All vegetables[g]		453.3		631
0.167	0.001	Corn	20.6		0.6	
0.167	0.025	Potatoes/potato products	159		131	
0.167	0.020	Leafy vegetables	58		38	
0.167	0.003	Legume vegetables	74		7	
0.167	0.025	Root vegetables	32		26	
0.167	0.002	Garden fruits[d]	38.1		2	
0.167	0.002	Tomatoes[e]	36.9		2	
0.167	0.002	Other fruits[f]	34.7		2	
0.167	--	All vegetables[g]		453.3		210
0.034	0.001	Corn	20.6		0.1	
0.034	0.025	Potatoes/potato products	159		27	
0.034	0.020	Leafy vegetables	58		8	
0.034	0.003	Legume vegetables	74		2	
0.034	0.025	Root vegetables	32		5	
0.034	0.002	Garden fruits[d]	38.1		0.5	
0.034	0.002	Tomatoes[e]	36.9		0.5	
0.034	0.002	Other fruits[f]	34.7		0.5	
0.034	--	All vegetables[g]		453.3		43

[a] See text for description of method by which uptake factors were derived (Section 2.3).
[b] Based on FDA Total Diet Studies - Adult Male, Southern, U.S.
[c] Source: U.S. DHEW, 1980.
[d] Includes commodities shown under "Garden Fruits", Table 2.6 except tomatoes.
[e] Includes fresh and canned tomatoes.
[f] Includes commodities shown under "Other Fruits", Table 2.6.
[g] Includes all vegetable commodities listed in Table 2.6

TABLE 2.14. PREDICTED PCB INTAKE FROM GARDEN VEGETABLES AND FRUITS GROWN ON SOIL CONTAINING 0.3 PPM PCB: CASE 1 - 100 PERCENT OF ANNUAL VEGETABLE INTAKE FROM GARDEN

Soil Dilution Factor	Plant Uptake Factor[a]	Food Group	Average Daily Consumption (grams)[b,c]	Daily Dietary Intake, ng/day
0.5	0.001	Corn	20.6	3
0.5	0.025	Potatoes/potato products	159	597
0.5	0.020	Leafy vegetables	58	174
0.5	0.003	Legume vegetables	74	33
0.5	0.025	Root vegetables	32	120
0.5	0.002	Garden fruits[d]	38.1	11
0.5	0.002	Tomatoes[e]	36.9	11
0.5	0.002	Other fruits[f]	34.7	10
0.5	--	All vegetables[g]	453.3	960
0.167	0.001	Corn	20.6	1
0.167	0.025	Potatoes/potato products	159	199
0.167	0.020	Leafy vegetables	58	58
0.167	0.003	Legume vegetables	74	11
0.167	0.025	Root vegetables	32	40
0.167	0.002	Garden fruits[d]	38.1	4
0.167	0.002	Tomatoes[e]	36.9	3
0.167	0.002	Other fruits[f]	34.7	3
0.167	--	All vegetables[g]	453.3	320
0.034	0.001	Corn	20.6	0
0.034	0.025	Potatoes/potato products	159	40
0.034	0.020	Leafy vegetables	58	12
0.034	0.003	Legume vegetables	74	2
0.034	0.025	Root vegetables	32	8
0.034	0.002	Garden fruits[d]	38.1	1
0.034	0.002	Tomatoes[e]	36.9	1
0.034	0.002	Other fruits[f]	34.7	1
0.034	--	All vegetables[g]	453.3	66

[a] See text for description of method by which uptake factors were derived (Section 2.3).
[b] Based on FDA Total Diet Studies - Adult Male, Southern, U.S.
[c] Source: U.S. DHEW, 1980.
[d] Includes commodities shown under "Garden Fruits", Table 2.6 except tomatoes.
[e] Includes fresh and canned tomatoes.
[f] Includes commodities shown under "Other Fruits", Table 2.6.
[g] Includes all vegetable commodities listed in Table 2.6.

TABLE 2.15. PREDICTED PCB INTAKE FROM GARDEN VEGETABLES AND FRUITS GROWN ON SOIL CONTAINING 0.3 PPM PCB: CASE 2 - 33 PERCENT OF ANNUAL VEGETABLE INTAKE FROM GARDEN

Soil Dilution Factor	Plant Uptake Factor[a]	Food Group	Average Daily Consumption (grams)[b,c]		Daily Dietary Intake, ng/day	
0.5	0.001	Corn	20.6		1	
0.5	0.025	Potatoes/potato products	159		196	
0.5	0.020	Leafy vegetables	58		57	
0.5	0.003	Legume vegetables	74		11	
0.5	0.025	Root vegetables	32		39	
0.5	0.002	Garden fruits[d]	38.1		4	
0.5	0.002	Tomatoes[e]	36.9		4	
0.5	0.002	Other fruits[f]	34.7		3	
0.5	--	All vegetables[g]		453.3		316
0.167	0.001	Corn	20.6		0	
0.167	0.025	Potatoes/potato products	159		65	
0.167	0.020	Leafy vegetables	58		19	
0.167	0.003	Legume vegetables	74		4	
0.167	0.025	Root vegetables	32		13	
0.167	0.002	Garden fruits[d]	38.1		1	
0.167	0.002	Tomatoes[e]	36.9		1	
0.167	0.002	Other fruits[f]	34.7		1	
0.167	--	All vegetables[g]		453.3		106
0.034	0.001	Corn	20.6		0	
0.034	0.025	Potatoes/potato products	159		13	
0.034	0.020	Leafy vegetables	58		4	
0.034	0.003	Legume vegetables	74		1	
0.034	0.025	Root vegetables	32		3	
0.034	0.002	Garden fruits[d]	38.1		0	
0.034	0.002	Tomatoes[e]	36.9		0	
0.034	0.002	Other fruits[f]	34.7		0	
0.034	--	All vegetables[g]		453.3		22

[a] See test for description of method by which uptake factors were derived (Section 2.3).
[b] Based on FDA Total Diet Studies - Adult Male, Southern, U.S.
[c] Source: U.S. DHEW, 1980.
[d] Includes commodities shown under "Garden Fruits", Table 2.6 except tomatoes.
[e] Includes fresh and canned tomatoes.
[f] Includes commodities shown under "Other Fruits", Table 2.6.
[g] Includes all vegetable commodities listed in Table 2.6.

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ATTACHMENT A

SEDIMENT SAMPLING DATA USED IN PATHWAYS ANALYSIS

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ATTACHMENT A

ATTACHMENT A. SEDIMENT SAMPLING DATA USED IN PATHWAYS ANALYSIS[a]

Contaminant	Concentrations (highest and second highest observed data)	Comments
Radionuclides		
Uranium	1006 ppm 163 ppm	1 percent U-235, 99 percent U-238 in secular equilibrium with U-234
Thorium	171 ppm 37 ppm	Natural Th-232 and Th-228
Plutonium		
Pu-238	10 pCi/g <8 pCi/g	
Pu-239/ Pu-240	<5 pCi/g 0.014 pCi/g	Pu-239/-240; treated as all Pu-239
Mercury	480 ppm 240[b]	Assumed to be inorganic Hg (based on less than one percent organic Hg)
PCB	0.6 ppm 0.3 ppm	Assumed to be all PCB 1248

[a] Includes background.
[b] Value is intermediate data point.

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ATTACHMENT B

GENERAL ASSUMPTIONS USED IN PATHWAYS ANALYSIS

ATTACHMENT B. (Continued)

Category	Assumptions
Inhalation and direct radiation scenario	• 16.0 hours per week in garden (2 hrs per day for six days and one 4-hour shift per week of rototilling; 150 days) • Resuspension factor of 5 x 10^{-8}/meter